Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

THE DUST OF THE UPPER AIR

JACQUES W. REDWAY, F.R.G.S.

Meteorological Laboratory, Mount Vernon, N. Y.

Two distinct shells of air compose the atmosphere. The plane of contact between them is approximately 7 miles above sea level, varying slightly with latitude and with the season. The upper shell has been explored to a height of about 20 miles, but extends many miles beyond. So far as known its movements are tidal rather than convectional. Its composition differs slightly from that of the convectional region also. If water vapor exists, the proportion is too minute to form cloud matter. Argon disappears at a height of 40 miles. Carbon dioxide is absent. Above 70 miles hydrogen, helium in minute proportions, and dust constitute practically all there is to the upper air. The diffusion of matter within the stratosphere follows the ordinary laws which govern such movements. Electrical disturbances of Hertzian-wave character are frequent in the upper air and these undoubtedly aid in the diffusion of its dust content, which apparently is highly ionized.

The lower shell of air is the convectional region. The laws of diffusion apply to its content, but convection is the chief factor in the mixture of its constituents. Aside from its lateral movements, the winds, there are also general vertical movements; air is both going up and coming down. The general movements of the air, rather than the laws of diffusion, govern the movements of its dust content.

Coarser particles picked up from the ground fall very quickly. Small particles, especially those of less than 1 micron, fall so slowly that, in many instances, the rate of fall is not measurable; indeed, highly ionized dust particles apparently do not fall at all. If they are brought to the ground it is because they become nuclei of condensation, and not by their own gravity. Even then, as soon as freed from their load of water, they escape into the air again. In other words the extremely fine dust particles behave much as does molecular matter. Especially is this the case when they are ionized—and possibly their ionization is constant.

The rate of fall of larger particles has been measured. Investigations carried on under the direction of the Transvaal Bureau of Mines show that particles 1 micron in dimension require about five hours to fall six feet. W. J. Humphreys finds that, at cloud height, particles 1.85 microns in dimension fall at the rate of 1 centimeter per 25 seconds, or a little more than 1 inch per minute. In this laboratory particles 1 micron in dimension require from 6 to 10 hours to fall 9 feet, the difference being due to the humidity of the air. In the past, elaborate calculations to demonstrate how swiftly or how slowly particles of given sizes may fall have been made; but observations to determine the rate at which they do fall are not many in number.

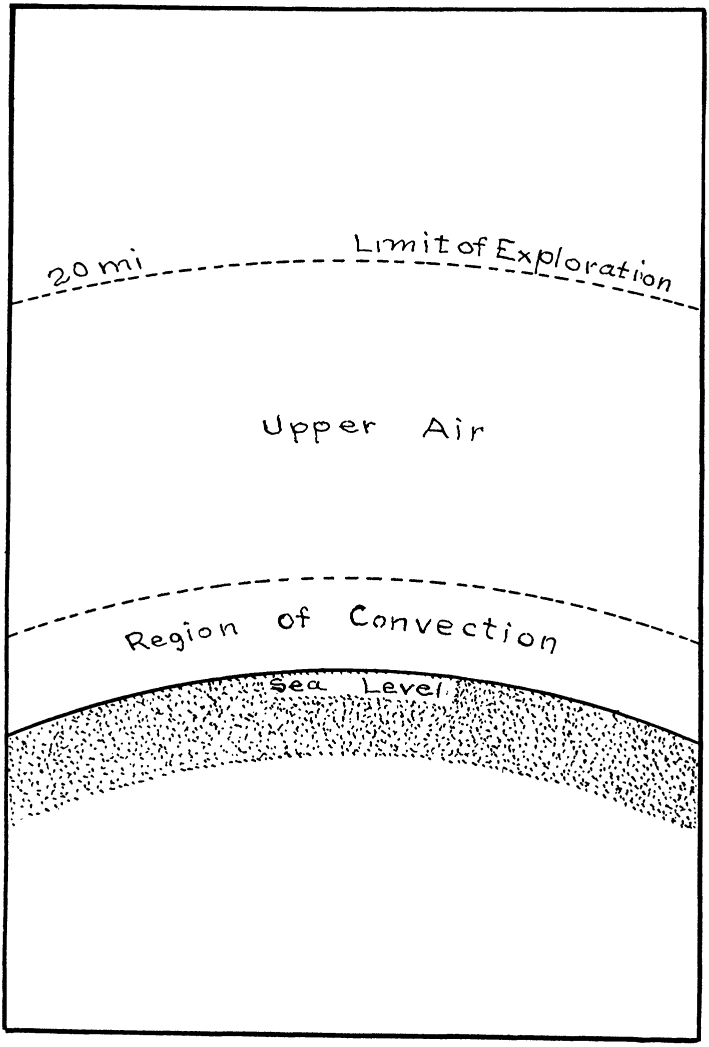

FIG. 1. Cross section of atmosphere.

In the region of convection, dust particles are nuclei of condensation. They are essential in the formation of fog and cloud substance. Rain and snow not only bring them to the ground, but also sweep the air free from floating matter of every sort. A snowstorm will rid the air of about everything except the blue haze. The air is never wholly free from dust, however; the cleanest free air carries from 10,000 to 20,000 dust particles per cubic inch.

The foregoing survey of the floating dust of the air is necessary to an understanding of its effects on certain irregularities in the temperature of the air. Floating dust—and the name is conveniently applied to slowly falling dust, as well—must be considered apart from wind-blown dust, which rarely is carried to a height of more than one to two thousand feet above ground.

Floating dust is mainly the product of volcanic energy. Most volcanic eruptions are steam explosions—that is, the escape of steam and probably other gases, under a pressure that must be reckoned in tons rather than in pounds per square inch. The gases, hydrogen, helium, and sulphur dioxide, along with a generous proportion of water, are a part of the rock which becomes volcanic ejecta. They are occluded within the magma which becomes lava. When the pressure is released the expansive force of the steam and gases blasts the lava into dust and shoots the dust twenty miles or more into the air.

The character of the dust bears evidence of the manner in which it is formed. Dust belched from Krakatoa was caught on slides at Los Angeles a year or more after the eruption. Petrologically the particles were identical with furnace slag. Physically most of them were bubbles of microscopic dimensions. Meteorologically, *en masse,* they formed a screen which intercepted so much of the sun's heat that for about two years the temperature of the air was materially lowered.[1]

The effect of a dust screen on temperature was pointed out by Benjamin Franklin. During the year 1783 the air was laden with dust from Asama, a volcano of Japan.[2] "Dry fogs prevailed over all Europe and a part of North America." "The sun's rays," adds Franklin, "were so faint in passing through it that, when collected in the focus of a burning glass, they would scarcely kindle brown paper." The warmth of the sun was so feeble that freezing temperatures began a month before their normal occurrence. "Delaware River was closed in November and remained ice-bound until late in March."

The period from 1812 to 1816 was one of unusual volcanic activity. Chief among the eruptions was that of a volcano in Tambora province, Sumbawa, an island near Java. The dust of this eruption diffused itself rapidly, probably from the fact that much of it remained in the region of convection. Dense clouds of dust of the coarser sort fell to the leeward of

---

[1] The statistics from many Weather Bureau stations report temperature means materially below normals for 1884–85. Records kept by the Keese family at Cooperstown, N. Y., for nearly seventy years, and continued by Elizabeth Cooper Keese, show that the mean temperature of 1885 was about 3 degrees below normal.

[2] A cinder cone near Skaptar-jokull, Iceland, was also in eruption that year.

Sumbawa at a distance of several hundred miles. A blanket of finer dust darkened the air more than one thousand miles away. There are no available data to the rate of movement of the dust clouds, but it is safe to assume that they were carried with wind velocity eastward in low latitudes, and finally swirled into the region of westerly winds in higher latitudes. General statistics concerning the effects of the dust screen on prevailing temperatures are absent, but a profusion of traditions marks the year 1816 as a summerless year. Popularly it was the year "eighteen hundred and froze to death." Thompson's History of Vermont gives a glimpse of climatic conditions in that state: "Snow fell and frosts occurred every month in that year. On the 8th of June snow fell in all parts of the state; on the upland it was five or six inches deep. It was accompanied by a hard frost, and on the 9th ice was half an inch thick on shallow standing water." That same year Professor Dewey of Williamstown, Mass., wrote: "There was cold weather every month this year; on June 7th a light snow."

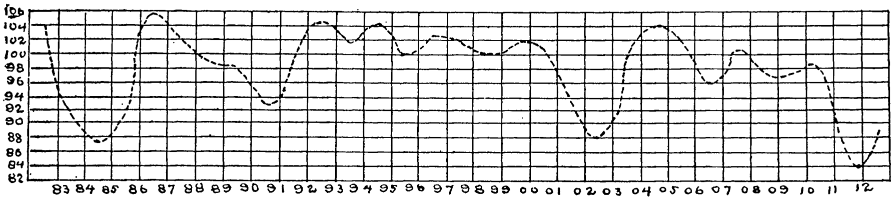

FIG. 2. Smoothed curve showing quantitatively the variations in solar radiation from 1883 to 1912.

Conclusions concerning the effect of a dust screen in the foregoing instances may not be wholly acceptable; the salient features, however, cannot be set aside, nor can they be doubted with good reason. Since 1883, Weather Bureau records in the matter are pretty complete. The accompanying diagram is a smoothed curve showing quantitatively the variations in solar radiation covering the period from 1883 to 1912. It is prepared from data observed by Langley, Abbot, and H. H. Kimball. The vertical row of figures shows the average percent of solar radiation received by the earth, 100 percent being normal. The horizontal line of figures is the series of calendar years. The variations are those in intensity of solar radiation, but indirectly they indicate variations in temperature. The depression of 1884 followed the dust clouds which were belched from Krakatoa. Tarawera, New Zealand, was in eruption about the same time. The depression of 1891–92 was coincident with the eruption of Bogoslov, a cinder cone of the Aleutian Islands. Bandai-san, a volcano of Japan, was active in 1888 and continued in action for several years. It is not unreasonable to suppose that its dust cloud was added to that of Bogoslov. The eruption of Mont Pelée preceded the cold spell of 1901–02. A Central American volcano was active about the same time. The low radiation value of 1911–12, less than 84 percent of normal, followed the eruption of Katmai, an Alaskan volcano.

One certainly may question the foregoing instances so far as cause is concerned, but one cannot question an effect that is so clearly apparent. One does not question the hypothesis that a cloud screens the earth from the heat of the sun; so does a parasol. And so far as the screening effect is concerned the only difference between a cloud and a dust pall is one of degree. Each is a parasol.

In presenting humanity with values that have a very practical application, Humphreys has gone a step farther than Franklin. He has measured the effect of the screen both ways with respect to radiation—both coming and going; and although his staggering array of equations might cause a layman to throw up his hands, one coefficient is quite intelligible to non-mathematical minds: namely, for every unit of the sun's heat coming to the earth but intercepted by the dust screen, thirty times as much heat is radiated by the earth into space.

Tests in this laboratory of an experimental sort, in the case of the ordinary blue haze, bear out the conclusions that apply to the screening effect of volcanic dust. Thus, at a designated temperature of the ordinary thermometer, a black-bulb thermometer registers from 10° to 20° lower when a haze is present than in clear air. During a dense haze a 4-inch burning glass failed to discolor test paper held at its focus. On the following day when the air was clear, and at practically the same temperature, the focal rays ignited the paper in a few seconds. This has occurred at this laboratory on two occasions. The test, though simple, is none the less conclusive in showing that dust in the air is a powerful factor in shutting out the heat of the sun. It appeals to laymen wholly unacquainted with the variations of the solar constant.

Statistics to show the effect of abnormally cold years on the death rate are not available—indeed, they have not been collected. One must bear in mind also that thermometer temperatures are not satisfactory measures of sensible heat. The variations of the solar constant are a far better measure of the effects of sun heat upon life than are thermometer temperatures. A hard-paved street or a rock surface may be deep a-slush with half-melted snow when the mercury of a thermometer is several degrees below the freezing point. At such times direct sunshine may burn the skin fiercely. A thermometer is therefore not an instrument satisfactory to the physiologist. Mortality statistics based on thermometer temperatures are apt to be faulty in the consideration of the death rate. But if the history of human suffering as detailed in the publications at the times of cold years go for evidence, one may safely conclude that the effects of a prolonged dust screen on life are profound.

But why is the continuation of the dust screen prolonged into months and even years—why does not rain or snow comb the dust out of the air? The answer is easy. The greater part of the fine dust of a volcanic explosion is shot into the stratosphere, the shell of the upper air, where there is neither rain nor snow, and where dust particles find no moisture to condense upon them. In this region of the air they fall so slowly—so very slowly, that months and years may elapse before they reach the region of convection where condensation removes them.